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Optimization of Drying-Infusion-Drying Processes in *Kilishi* Production

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Authors' contributions

This work was carried out in collaboration between all authors. Author AOA designed the study, performed the statistical analysis wrote the protocol and the first draft of the manuscript. Authors CTA and JOI managed the analyses of the study. Author CTA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To apply Box-Behnken Response Surface Methodology in obtaining optimum conditions for first drying and infusion-second drying stages in *Kilishi* production.
Study Design: Thin slices/strips of beef were subjected to drying under varying conditions. Moisture Loss and Yield was determined.
Place and Duration of Study: UNIBEN Kilishi factory, University of Benin, Edo, Nigeria; Food Processing Laboratory, Obafemi Awolowo University, Ile-Ife, Nigeria between December 2014 and June 2015.
Methodology: The independent variables for the first drying stage were meat thickness (3 mm – 5 mm), drying temperature (40 – 60°C) and drying time (3 – 5 h) with moisture loss being the response. For the infusion-second stage drying, the independent variables were ingredient concentration (50 – 70%), infusion time (20 – 40 min), drying temperature (40 - 60°C) and drying time (4 – 6 h) while the response was apparent yield. Surface and Contour maps were generated.
Results: The optimum conditions for first stage drying were 3 mm meat thickness, 60°C drying temperature and a drying time of 3 h, with an optimum moisture loss of 63.19%. For the infusion-

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second drying process, the optimum conditions were 66% ingredient concentration, 20 min infusion time, 60°C drying temperature and drying time of 4 h with optimum yield of 62%. The processing time was reduced from 72 hours to 7.5 h.
Conclusion: These conditions obtained can be employed for large scale industrial processing.

Keywords: Box-Behnken; optimum; dried meat; contour.

1. INTRODUCTION

Kilishi is an intermediate moisture meat product that is prepared essentially from beef slices, infused in a slurry of defatted groundnut paste and spices and sun-dried [1]. It is a ready-to-eat convenience meat product possessing excellent shelf stability at room temperature, making handling and marketing of the product convenient for consumers and retailers alike [2] Similar products in the northern region of Nigeria include *Balangu, Kundi, Dambu Nama* etc. The consumption of these products has extended to other parts of the country [3].

Kilishi is prepared by partially drying thin sheets of quality beef in the sun followed by addition of some ingredients before a second period of sun drying and partial roasting [1,4]. This method of production is still largely rural with little or no standard and technological indices in spite of the new process and product technology [5]. In a study by [6], there is a failure in Africa's agriculture which is largely due to the disconnection between farmers, availability of appropriate production technologies, empirical research findings, appropriate agro-processes, the markets and consumer appreciation. Indigenous product technologies can only be sustainably upgraded by improved value-chain systems, capacity building and sustainable technological developments. Traditional *Kilishi* processing usually takes between 24 – 48 hours and is dependent on the amount of insolation. Modern processing has explored the use of solar drying [7] and its effect on the nutritional quality and sensory attributes of the final product.

Response Surface Methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes [8]. It has been successfully used to improve process and product performance in food systems as reported by several researchers [9-12]. Several researches on the traditional production of *Kilishi* have been reported [13,14]. However, no comprehensive study has been carried out to optimize the parameters involved in the drying-infusion-drying processes. Hence this study applied Box-Behnken design in obtaining optimum conditions for the unit operations in *Kilishi* production mainly first and second stage drying respectively.

2. MATERIALS AND METHODS

2.1 Materials

Meat from the hindquarters of freshly slaughtered cow was purchased from an abattoir in Ile-Ife, Osun State, Nigeria. The materials for ingredient mix preparation were also purchased from the local market in Ile-Ife.

2.2 *Kilishi* Production

Kilishi samples were prepared using a modified method [1,13] as shown in the flow chart in Fig. 1. The meat was sliced using a mechanical meat slicer (SCARFEN 58452, Type ATM 3) into thin sheets of pre-determined thickness and dried in a a hot air rotary dryer (located at the Uniben *Kilishi* factory, University of Benin, Benin, Nigeria) at temperatures of 40, 50 and 60°C, respectively at a constant air velocity of 1.0 m/s (digital Anemometer) to a moisture content of about 40% wet basis. The ingredient mix was prepared according to [15] and the dried spices were cleaned, milled and sieved using USA No.14 mesh standard sieve. The dried sheets were infused in slurry of ingredient mix for about 30 min before being returned into the dryer for another drying to a moisture content of 15% or less. The dried product was transferred to a charcoal roasting oven for impartation of smoky flavor.

2.3 Process Optimization

The first drying stage and second drying stage were optimized using response surface methodology. The experimental design for setting up the variables needed for each process is as shown in Tables 1 and 2, respectively. The experimental data were analyzed by multiple regression and used to develop a model according to the following quadratic polynomial equation

$$Y = A_0 + \sum A_i X_i + \sum A_{ii} X_{ii}^2 + \sum\sum A_{ij} X_i X_j + \text{error} \quad (1)$$

Where, Y is the predicted response, A_o is the constant and A_i, A_{ii}, A_{ij} are the regression coefficients of the model obtained by multiple regression (which represents the linear, quadratic and cross-product effects of the response respectively) and X_i, X_j represent the independent variables.

The independent variables for the first drying stage were meat thickness (3 mm – 5 mm), drying temperature (40 – 60°C) and drying time (3 – 5 h) with moisture loss being the measured response. For the second stage drying, the independent variables were ingredient concentration (50 – 70%), infusion time (20 – 40 min), drying temperature (40 - 60°C) and drying time (4 – 6 h) while the response measured was apparent yield. The values for these variables were chosen to be within range of the traditional processing conditions as reported by [4] and confirmed in a preliminary study.

The multiple regression analysis, optimization and ANOVA was carried out using the statistical software STAT-EASE Design Expert 8.0.5 (Trial Version) to fit quadratic polynomial equations for all response variables.

2.4 Moisture Loss Determination

Moisture loss from the meat slices during drying was calculated as

$$\text{Moisture Loss} = \frac{\text{Initial weight} - \text{Weight after drying}}{\text{Initial weight}} \quad (2)$$

2.5 Yield Determination

Apparent yield was calculated using the method of Igene et al. [1]

$$\%\text{Yield} = \frac{\text{weight of Kilishi before infusion}}{\text{weight after smoking}} \times 100 \quad (3)$$

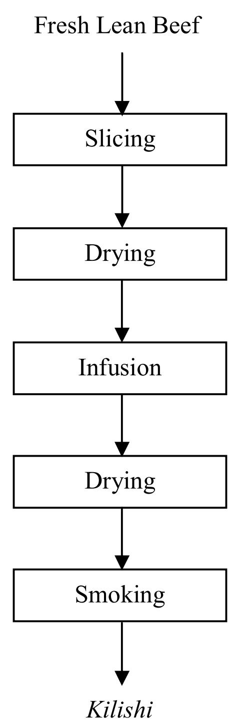


Fig. 1. Flowchart for *Kilishi* production

Source: Igene [13]

Table 1. Box-behnken design matrix and the responses of the dependent variable, moisture loss

Run	Meat thickness (mm)	Drying temperature (°C)	Drying time (h)	Moisture loss (%)
1	4.00	50.00	4.00	66.87 ± 0.70
2	3.00	50.00	3.00	66.94 ± 0.96
3	3.00	40.00	4.00	67.90 ± 0.99
4	4.00	60.00	3.00	73.54 ± 0.76
5	5.00	60.00	4.00	67.62 ± 1.12
6	4.00	40.00	3.00	73.78 ± 1.01
7	3.00	60.00	4.00	70.88 ± 1.08
8	4.00	50.00	4.00	58.97± 0.96
9	3.00	50.00	5.00	68.32 ± 0.61
10	4.00	60.00	5.00	34.39 ± 1.41
11	4.00	50.00	4.00	67.67 ± 0.99
12	5.00	50.00	5.00	58.20± 1.21

Run	Meat thickness (mm)	Drying temperature (°C)	Drying time (h)	Moisture loss (%)
13	5.00	40.00	4.00	69.78 ± 0.53
14	4.00	40.00	5.00	76.28 ± 0.93
15	4.00	50.00	4.00	64.36 ± 1.22
16	4.00	50.00	4.00	53.28 ± 1.28
17	5.00	50.00	3.00	60.61 ± 0.78

Table 2. Box-Behnken design matrix and the response of the dependent variable, apparent yield (%)

Run	Ingredient concentration (% solids)	Infusion time (min)	Drying temperature (°C)	Drying time (h)	Apparent yield (%)
1	70.00	30.00	50.00	4.00	63.76 ± 0.23
2	50.00	30.00	40.00	5.00	63.63 ± 0.15
3	60.00	30.00	50.00	5.00	63.05 ± 0.21
4	60.00	30.00	50.00	5.00	67.58 ± 0.33
5	60.00	30.00	50.00	5.00	59.80 ± 0.24
6	50.00	40.00	50.00	5.00	62.33 ± 0.46
7	60.00	20.00	50.00	4.00	65.23 ± 0.18
8	70.00	30.00	50.00	6.00	69.46 ± 0.64
9	50.00	30.00	50.00	6.00	51.82 ± 0.47
10	70.00	20.00	50.00	5.00	46.82 ± 0.35
11	60.00	30.00	40.00	4.00	63.50 ± 0.26
12	60.00	20.00	40.00	5.00	58.73 ± 0.13
13	50.00	20.00	50.00	5.00	66.16 ± 0.35
14	50.00	30.00	60.00	5.00	66.47 ± 0.68
15	70.00	30.00	40.00	5.00	63.45 ± 0.73
16	60.00	30.00	40.00	6.00	65.76 ± 0.44
17	60.00	30.00	50.00	5.00	59.86 ± 0.75
18	60.00	40.00	50.00	4.00	53.80 ± 0.65
19	50.00	30.00	50.00	4.00	53.54 ± 0.49
20	60.00	30.00	60.00	6.00	62.84 ± 0.54
21	60.00	40.00	50.00	6.00	64.52 ± 0.43
22	60.00	40.00	40.00	5.00	47.38 ± 0.37
23	70.00	40.00	50.00	5.00	63.86 ± 0.19
24	60.00	30.00	60.00	4.00	53.75 ± 0.21
25	60.00	30.00	50.00	5.00	66.19 ± 0.36
26	70.00	30.00	60.00	5.00	58.72 ± 0.55
27	60.00	20.00	50.00	6.00	51.03 ± 0.67
28	60.00	20.00	60.00	5.00	71.35 ± 0.43
29	60.00	40.00	60.00	5.00	63.47 ± 0.66

3. RESULTS AND DISCUSSION

3.1 First Stage Drying

The results in Table 1 illustrate the considerable variation in the moisture loss from the meat slices under various drying conditions. The loss in moisture ranged from 34.39% (run 10) to 76.28% (run 14). The model terms as shown in Table 3 were not significant despite a non-significant lack of fit which is desirable as the aim of the study is for the model to fit. A 2FI (two-factor interaction) model was suggested and explored to obtain the coefficient estimates of the factors. The final equation in terms of the coded factors is

$$Moisture\ loss = 64.67 - 3.08A + 3.92B - 3.94C + 1.23AB - 1.88AC + 9.31BC \quad (4)$$

The positive coefficients of drying temperature (B), and the interaction terms drying temperature and meat thickness (AB), drying temperature and drying time (BC) indicate a direct effect of these variables on moisture loss. The fit of the model is expressed by the coefficient of determination, R^2, (0.4450) which indicates that 44.50% of the variability in the response could be explained by the model. The adequacy of precision is the calculated ratio of 4.452 which is a little above 4 indicating a barely adequate signal. Tables 3 and 4 show the regression coefficients and their corresponding p-values. The p-value serves as a tool for checking the significance of each coefficient. Smaller p-values indicate a higher level of significance for the corresponding coefficient [16]. From the model (Equation 4), it can be observed that the interaction of drying temperature and drying time (BC) had a significant effect due to its large coefficient followed by that of drying temperature (B). From Table 3, it can be deduced that none of the terms is significant at both 1 and 5% levels.

Nevertheless, from the p-values obtained, the interaction effect of drying temperature and drying time had the least value further confirming the significance of this interaction to the model. Of the main effects, drying temperature and drying time had low p-values compared to meat thickness. This confirms that in the first stage drying of meat/beef slices for *Kilishi* production, the thickness of the meat within the levels tested is not significant to the amount of moisture that will be lost given that the studied drying temperature and time are maintained.

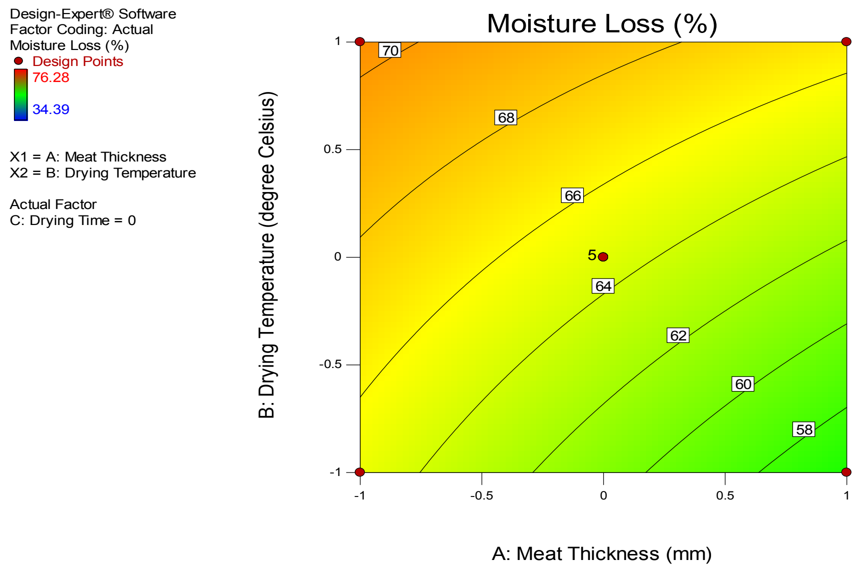
By differentiating Equation 4 and solving for values of A, B and C, at 91.1% desirability, Meat Thickness (A) = 3 mm, Drying Temperature (B) = 60°C and Drying Time (C) = 3 h. Based on the results obtained in the model, the optimum moisture loss using the above conditions = 63.19%. The regression model was employed to develop response surface and contour plots as shown in Figs. 2, 3 and 4. The contour plots provide a visual interpretation of the interaction between two variables. The shapes of the contour plots provide a measure of the significance of the mutual interaction between the variables. A circular contour plot indicates that the interactions between related variables are negligible while an elliptical contour plot indicates a significant interaction.

The contour plots in Figs. 2 and 3 are circular indicating that the interaction between meat thickness and drying time and temperature respectively is negligible during the drying period while the contour plot in Fig. 4 is elliptical in shape which confirms the significant interaction between drying time and temperature. As drying temperature increased and meat thickness increased, there was a reduction in amount of moisture lost as depicted in Fig. 2. This could be as a result of case hardening which is known to occur during drying at low moisture content and high temperature. During this phenomenon, moisture is removed from the surface of the material much faster than it is removed from within the material. The dried out surface now becomes a hardened layer making further drying much slower than expected [17]. A similar trend is also observed in Fig. 3 that as drying time increases and meat thickness increases, moisture loss reduces. In Fig. 4, as drying temperature and drying time increases, moisture loss also increases. This indicates a direct relationship between these variables during the drying process.

Table 3. Analysis of variance table for response surface 2FI model Response: Moisture Loss

Source	Sum of squares	df	Mean Square	F-value	p-value
Model	689.88	6	114.98	1.34	0.3261
A-Meat Thickness	75.83	1	75.83	0.88	0.3699
B-Drying Temperature	123.09	1	123.09	1.43	0.2592
C-Drying Time	124.11	1	124.11	1.44	0.2574
AB	6.05	1	6.05	0.070	0.7962
AC	14.10	1	14.10	0.16	0.6941
BC	346.70	1	346.70	4.03	0.0725
Residual	860.25	10	86.02		
Lack of Fit	457.46	6	76.24	0.76	0.6384
Pure Error	402.79	4	100.70		0.3261
Cor Total	1550.13	16			

Std. Dev = 9.27, Adeq precision = 4.452, Mean = 64.67, R-squared = 0.4450, Adj R-squared = 0.1121, Pred R-squared = -0.7767



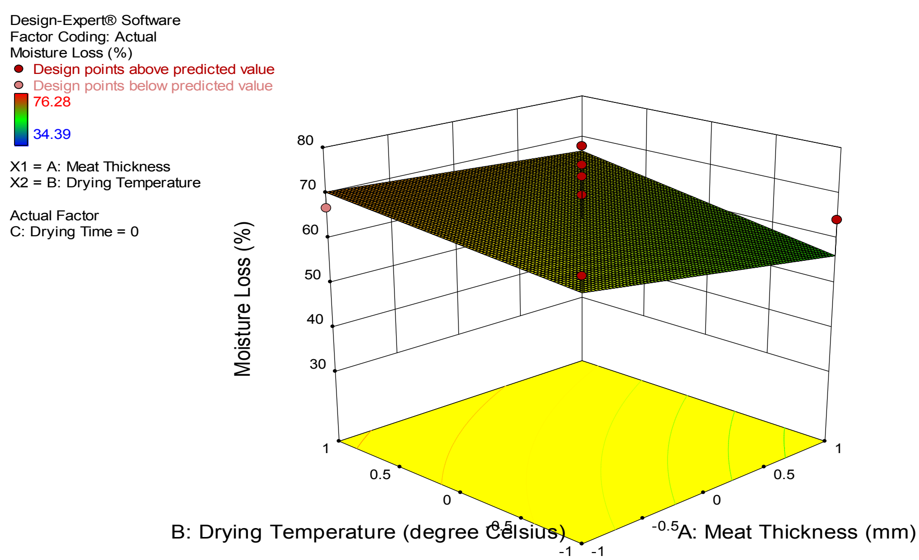
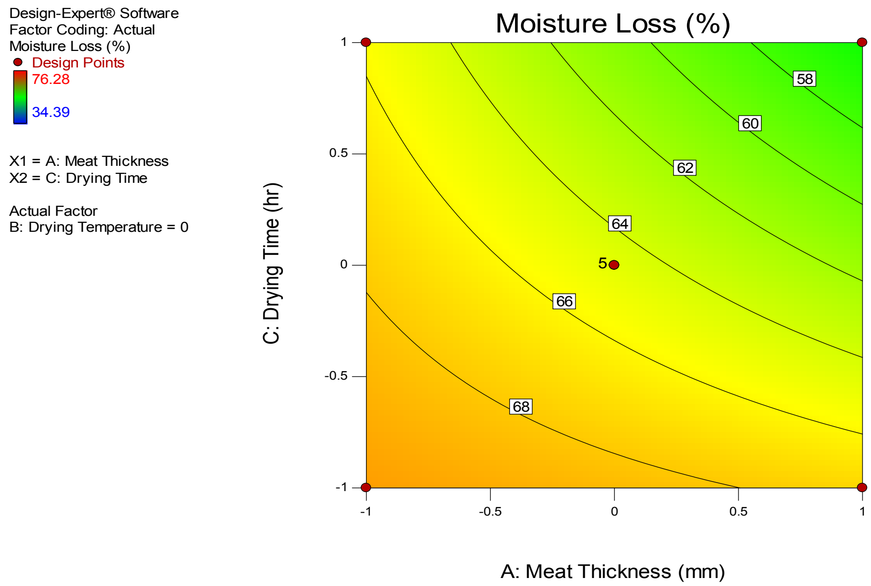


Fig. 2. (a) Response surface plot of moisture loss (b) The contour plot showing the combined effects of drying temperature and meat thickness on moisture loss

Table 4. Significance test of regression coefficients for apparent yield

Parameter	Estimate	Standard error	p-value
Intercept	63.80	2.09	0.0340
A – Concentration of Slurry	2.07	1.35	0.1489
B – Infusion Time	-1.91	1.35	0.1791
C – Drying Temperature	2.72	1.35	0.0638
D – Drying Time	1.00	1.35	0.4713
AB	1.08	2.34	0.6502
AC	2.64	2.34	0.2776
AD	1.94	2.34	0.4201
BC	3.02	2.34	0.2173

Parameter	Estimate	Standard error	p-value
BD	1.02	2.34	0.6682
CD	1.82	2.34	0.4493
A^2	-7.66	1.84	0.0010
B^2	2.56	1.84	0.1857
C^2	-2.80	1.84	0.1497
D^2	1.04	1.84	0.5796



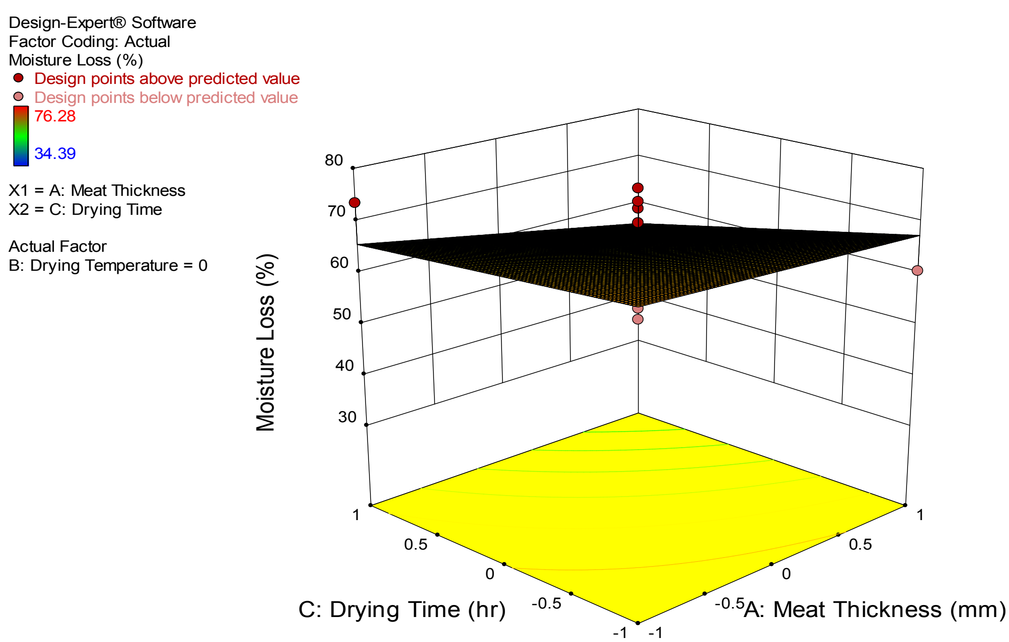


Fig. 3. (a) Response surface plot of moisture loss (b) The contour plot showing the combined effects of drying time and meat thickness on moisture loss

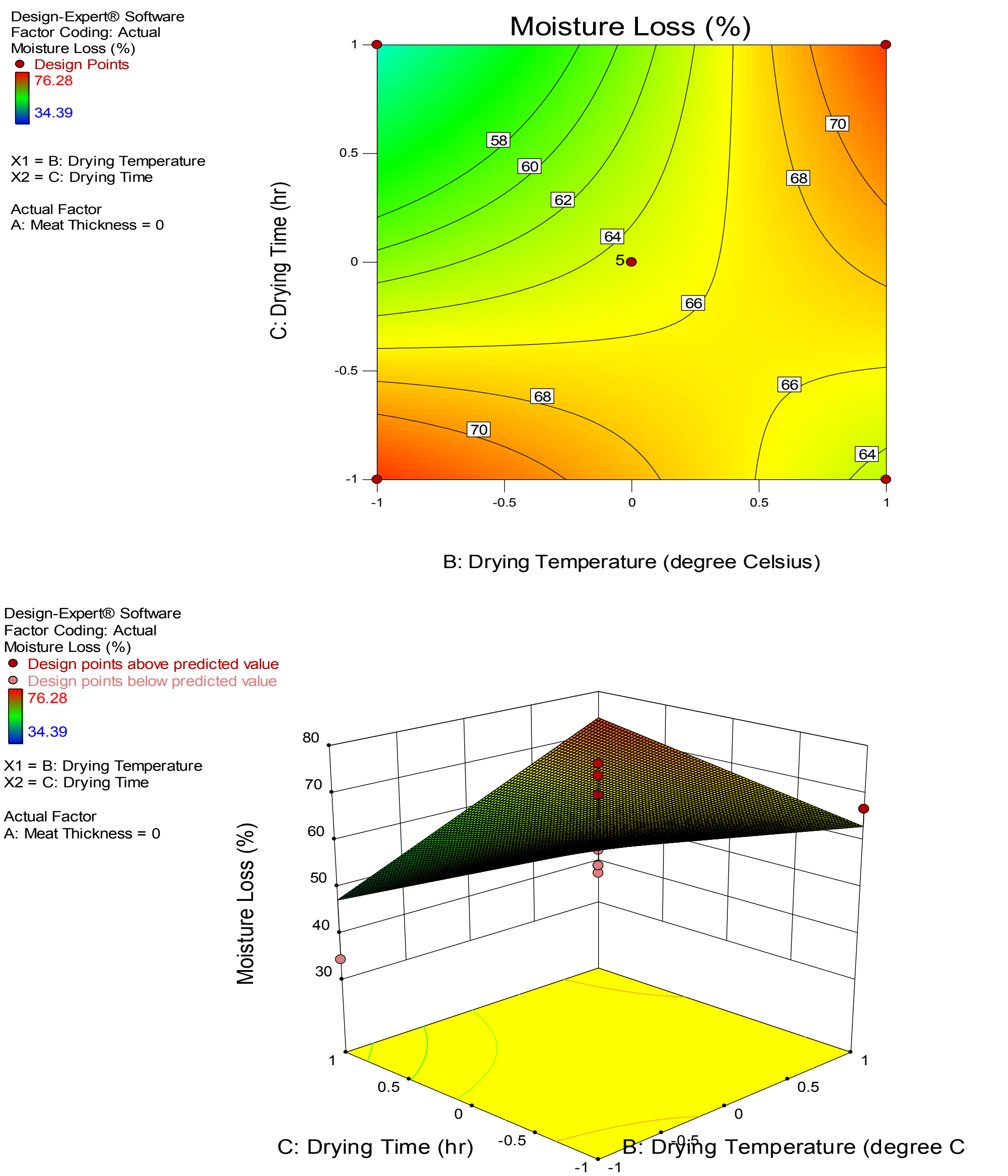


Fig. 4. (a) Response surface plot of moisture loss (b) The contour plot showing the combined effects of drying time and drying temperature on moisture loss

3.2 Infusion Process and Second Stage Drying

As shown in Table 2, the apparent yield obtained during *Kilishi* processing ranged from 46.82% (run 10) to 71.35% (run 28). The model obtained by carrying out multiple regression analysis on the data obtained is shown in equation 5.

$$Apparent\ Yield = 63.80 + 2.07A - 1.91B + 2.72C + 1.00D + 1.08AB + 2.64AC + 1.94AD + 3.02BC + 1.02BD + 1.82CD - 7.77A^2 + 2.56B^2 - 2.80C^2 + 1.04D^2. \quad (5)$$

From Equation 5, all interaction effects had positive coefficients indicating a direct relationship between these effects and the yield after drying. Of the linear effects, only B had a negative coefficient while the quadratic effects of A and C also show an inverse relationship with shrinkage. The model F-value of 2.75 (Table 5) implies the model is significant and there is only a 3.4% chance that an F-value this large could occur due to noise. The fit of the model according to the coefficient of determination (R^2) was given as 0.7336 which implies that 73.36% of the variability in the response could be explained by the model. The predicted R^2 of -0.4292 implies that the overall mean is a better predictor of the response than the current model. The ratio of the signal to noise (5.730) indicates an adequate signal thus the model can be used to navigate the design space. From the significance test shown in Table 6, drying temperature and the quadratic effect of concentration of the slurry were significant at 5% level.

By solving Equation 5 for values of A, B, C and D, at 87.7% desirability the following optimum conditions were obtained, Ingredient Concentration (A) = 66%, Infusion Time (B) = 20 min, Drying Temperature (C) = 60°C, Drying Time (D) = 4 h. Based on the results obtained in the model, the optimum apparent yield is 62%.

The aim of optimizing the combined unit operations of infusion and second stage drying was to get a maximally dried out product as depicted by the apparent yield since the meat slices after infusion were thicker due to moisture and ingredient absorption. From the contour and response surface plots (Fig. 5 – 10), the combined effects of drying time and concentration of slurry, drying temperature and infusion time, drying time and infusion time, drying time and drying temperature had a direct effect on the yield. In a study [17] to optimize the infusion stage in *Kilishi* processing by determining the effect of variation in ingredient composition, the amount of water added in making the ingredient slurry was found to significantly affect the adherence of ingredient to the meat slices. The findings of this present study agrees with the report as an increase in the levels of these effects (drying temperature, drying time, ingredient concentration and infusion time) would bring about an increase in yield, implying that the longer the meat slices stay being infused with the slurry, the longer the time of drying out to obtain an optimally shrunk (as an index of drying) product. This observation also clearly agrees with [4] who reported longer drying periods with long infusion time. Also, to prevent caking of the slurry on the meat surface, the longer the time of infusion the longer the drying time at constant temperature.

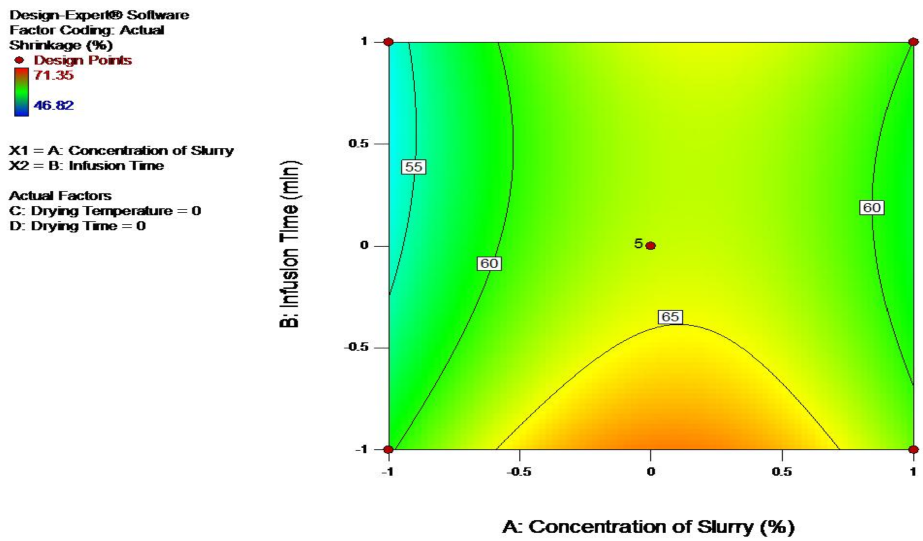
During the drying of food materials, moisture removal at the beginning of drying is by evaporation [1,18] and as drying progresses, diffusion takes over as the underlying mechanism. Since the surface of the material becomes slightly dry, moisture cannot move from within the material as fast as it can evaporate from the surface. This in turn affects the level of shrinkage of the product and yield at the end of drying. However, an increase in concentration of slurry as drying temperature increased reduced the level of shrinkage. This was due to cake formation arising from adhering slurry during infusion which preventing the heat from penetrating the slices.

Table 5. Analysis of variance table for response surface quadratic model Response: Apparent yield

Source	Sum of squares	df	Mean square	F-value	p-value
Model	845.23	14	60.37	2.75	0.0340
A-Concentration of Slurry	51.17	1	51.17	2.33	0.1489
B-Infusion Time	43.85	1	43.85	2.00	0.1791
C-Drying Temperature	88.84	1	88.84	4.05	0.0638
D-Drying Time	12.02	1	12.02	0.55	0.4713
AB	4.71	1	4.71	0.21	0.6502
AC	27.98	1	27.98	1.28	0.2776
AD	15.13	1	15.13	0.69	0.4201
BC	36.60	1	36.60	1.67	0.2173
BD	4.20	1	4.20	0.19	0.6682
CD	13.29	1	13.29	0.61	0.4493
A^2	380.21	1	380.21	17.34	0.0010

Source	Sum of squares	df	Mean square	F-value	p-value
B^2	42.47	1	42.47	1.94	0.1857
C^2	50.94	1	50.94	2.32	0.1497
D^2	7.05	1	7.05	0.32	0.5796
Residual	306.96	14	21.93		
Lack of Fit	278.05	10	27.80	3.85	0.1030
Pure Error	28.91	4	7.23		
Cor Total	1152.19	28			

Std. Dev = 4.68, Adeq precision = 5.730, Mean = 60.96, R-squared = 0.7336, Adj R-squared = 0.4672, Pred R-squared = -0.4292



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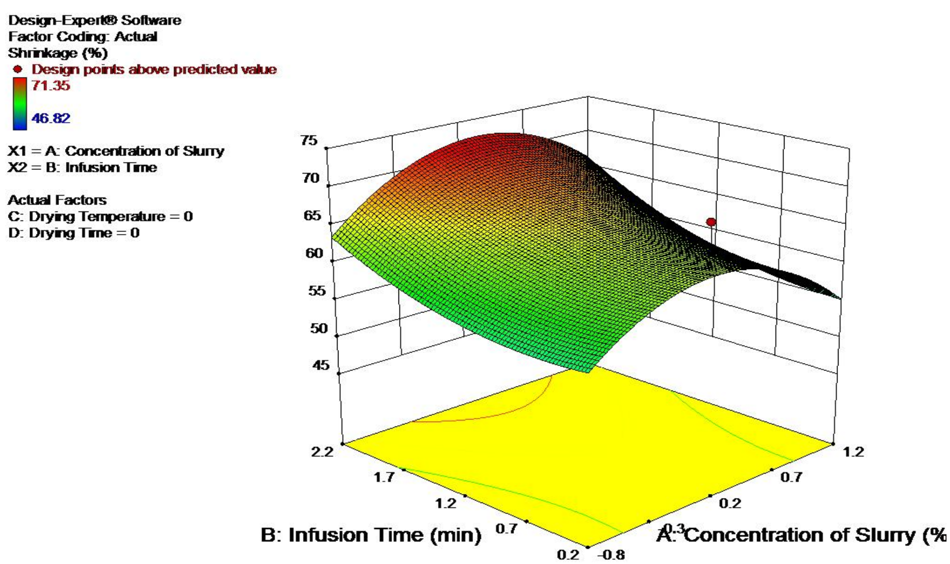

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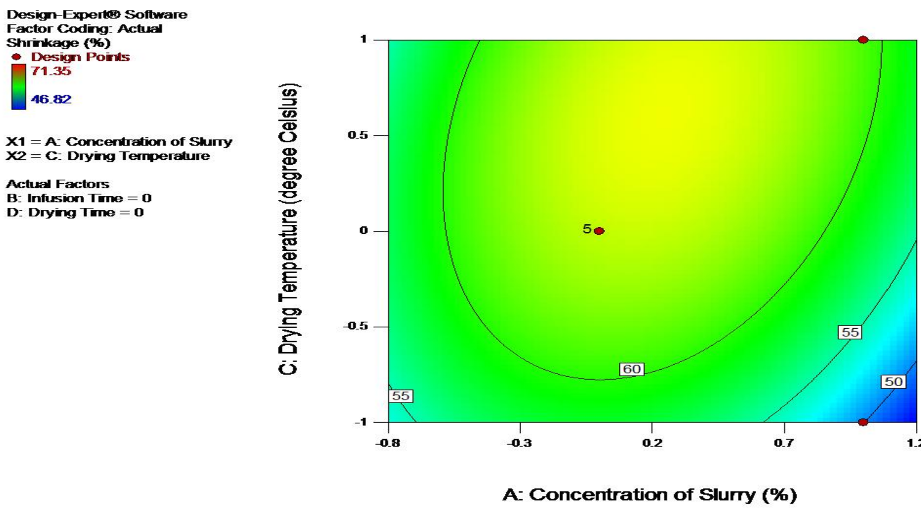
Fig. 5. (a) Response surface plot of apparent yield (b) The contour plot showing the combined effects of infusion time and concentration of slurry on apparent yield



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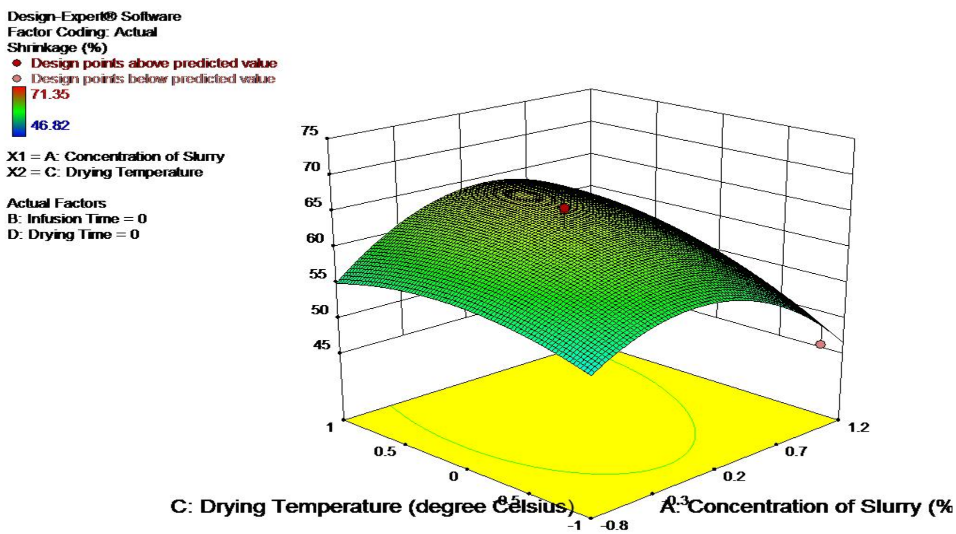


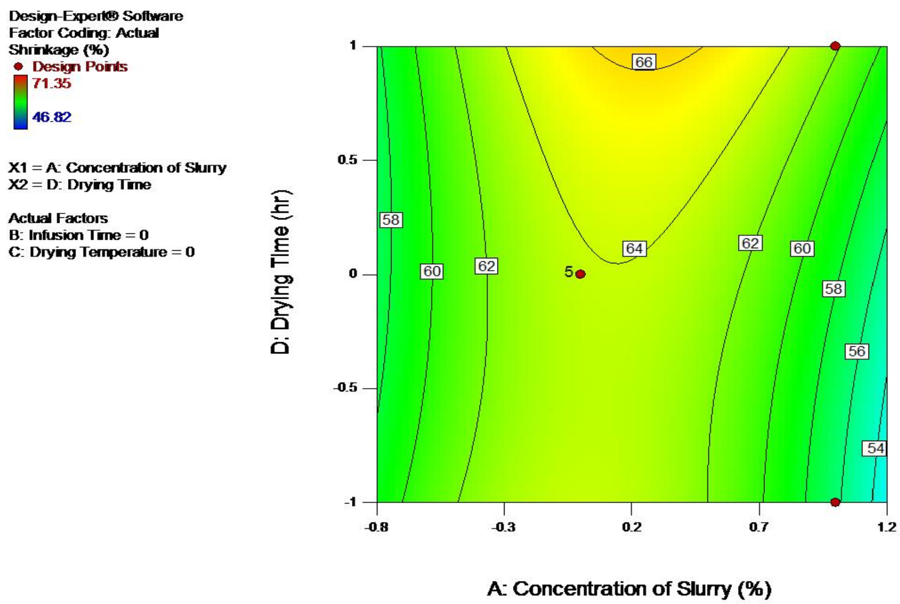
(b)

Fig. 6. (a) Response surface plot of apparent yield (b) The contour plot showing the combined effects of drying temperature and concentration of slurry on the apparent yield

Table 6. Significance test of regression coefficients for apparent yield

Parameter	Estimate	Standard error	p-value
Intercept	63.80	2.09	0.0340
A – Concentration of Slurry	2.07	1.35	0.1489
B – Infusion Time	-1.91	1.35	0.1791
C – Drying Temperature	2.72	1.35	0.0638
D – Drying Time	1.00	1.35	0.4713
AB	1.08	2.34	0.6502
AC	2.64	2.34	0.2776
AD	1.94	2.34	0.4201
BC	3.02	2.34	0.2173

Parameter	Estimate	Standard error	p-value
BD	1.02	2.34	0.6682
CD	1.82	2.34	0.4493
A^2	-7.66	1.84	0.0010
B^2	2.56	1.84	0.1857
C^2	-2.80	1.84	0.1497
D^2	1.04	1.84	0.5796



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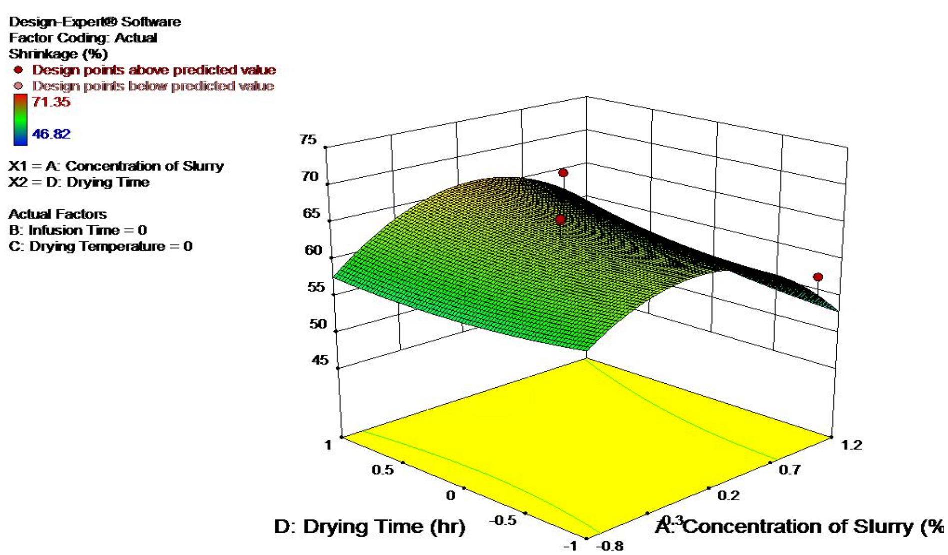
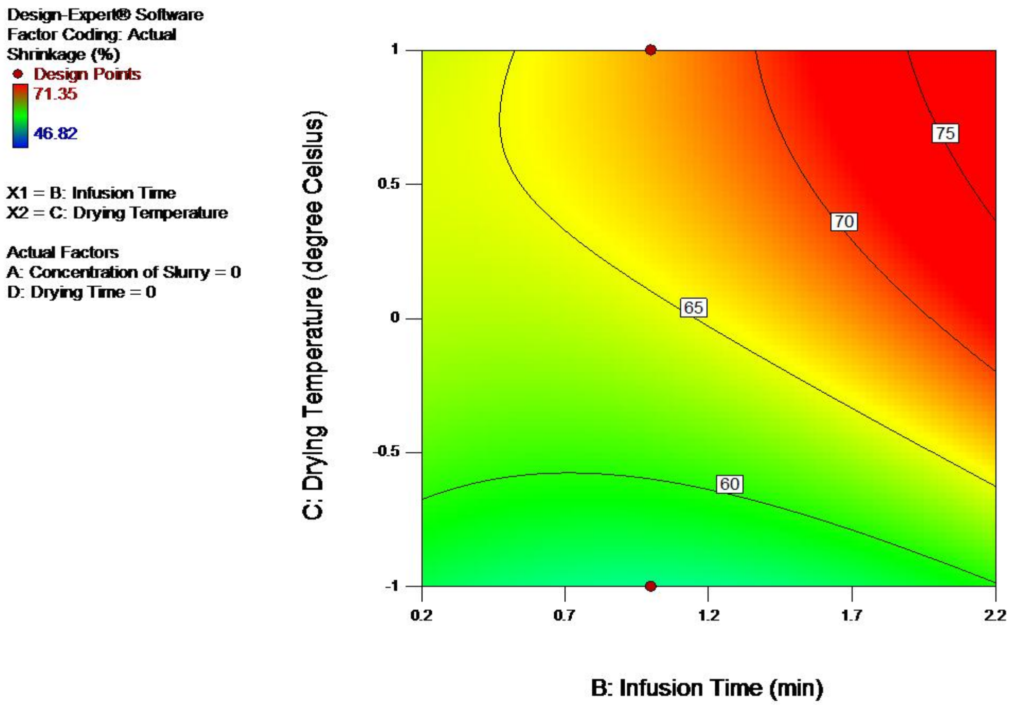
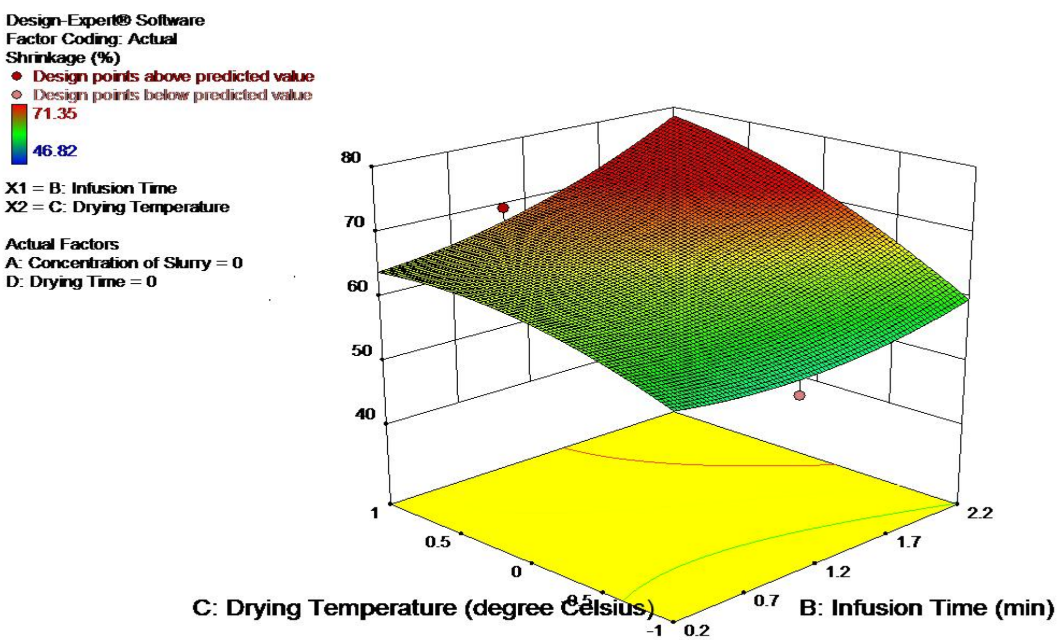


(b)

Fig. 7. (a) Response surface plot of apparent yield (b) The contour plot showing the combined effects of drying time and concentration of slurry on the apparent yield



(a)



(b)

Fig. 8. (a) Response surface plot of apparent yield (b) The Contour plot showing the combined effects of drying temperature and infusion time on the apparent yield

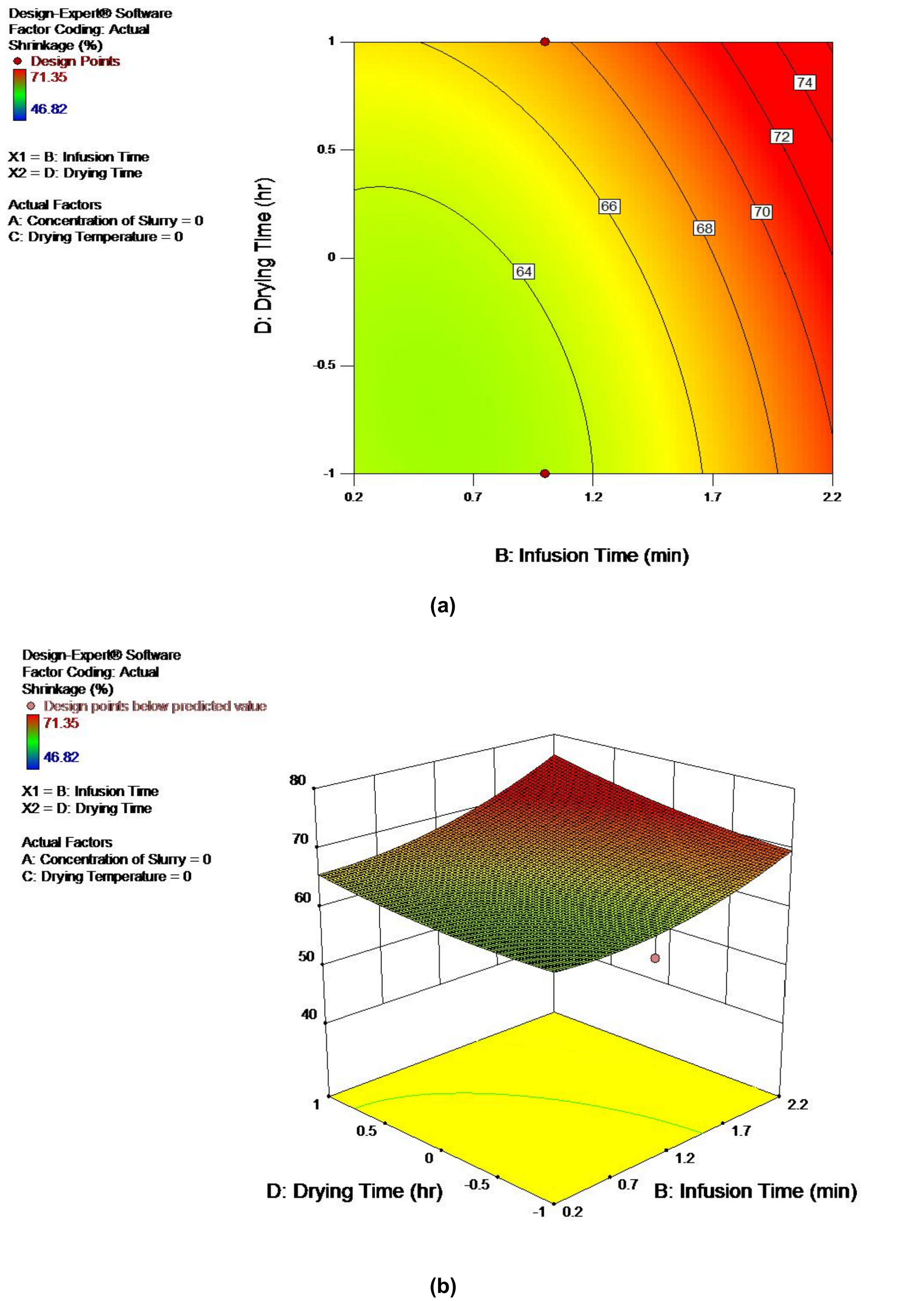
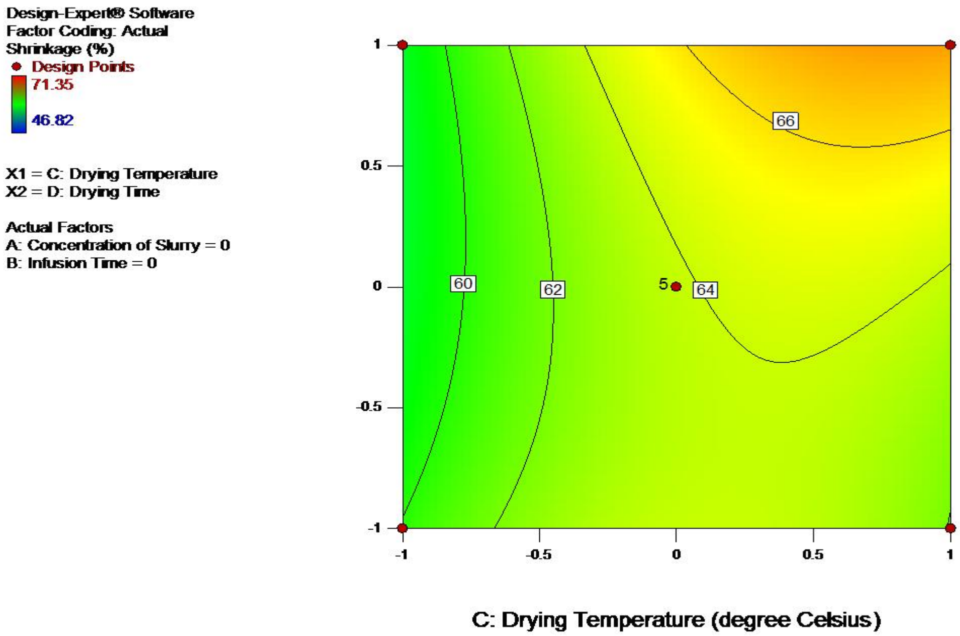
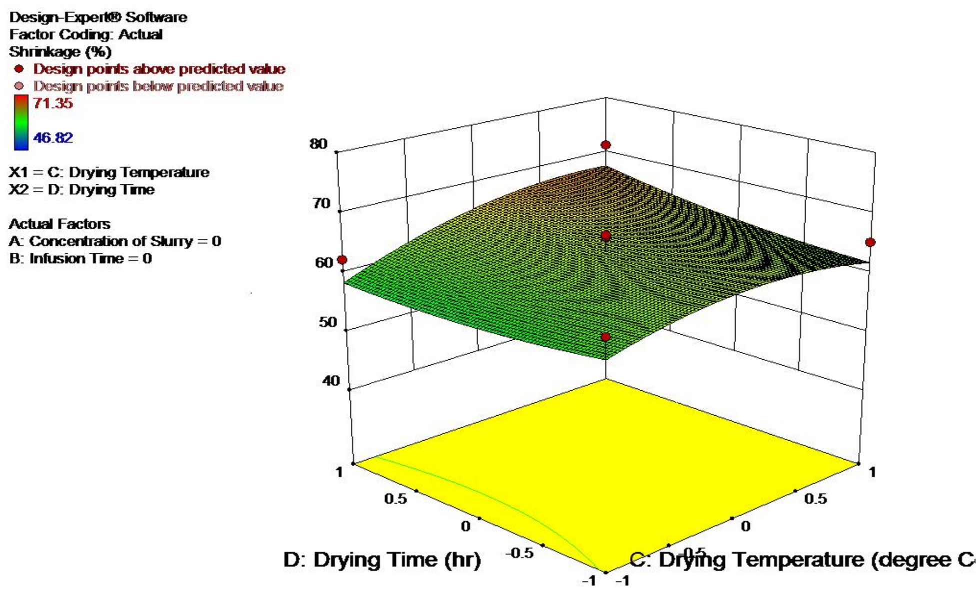


Fig. 9. (a) Response surface plot of apparent yield (b) The contour plot showing the combined effects of drying time and infusion time on the apparent yield



(a)



(b)

Fig. 10. (a) Response surface plot of apparent yield (b) The contour plot showing the combined effects of drying time and drying temperature on the apparent yield

4. CONCLUSION

Response Surface Methodology was successfully used to determine the optimum conditions for the first stage drying of meat slices in *Kilishi* preparation as well as the second stage drying and infusion processes. Processing time was reduced to approximately eight hours. The study showed that the thickness of meat within the range studied does not significantly affect the amount of moisture loss from the meat slices during the first stage drying. These conditions i.e. the results of this work can be employed in large scale, mechanized production of *Kilishi*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Igene JO, Farouk MM, Akanbi CT. Preliminary studies on the traditional processing of Kilishi. Journal of Food Science and Agriculture. 1990;50:89-98.
2. Olusola OO. Quality variations and the nutritive attributes of differently processed and packaged Kilishi products. PhD Thesis, University of Ibadan; 2006.
3. Inyang CU, Inyor MA, Uma EN. Bacteriological quality of a smoked meat product (suya). Nigeria Food Journal. 2005;23:239–242.
4. Musonge P, Njolai EN. Drying and infusion during the traditional processing of Kilishi. Food Engineering. 1994;23:159–168.
5. Igene JO. Capacity building in food security in Nigeria: The missing links. Lambert Acad. Publ., Germany. 2009a;96.
6. Igene JO. Traditional african meat products for food security and agro-industrialisation: Development challenges. Lambert Acad. Publ., Germany. 2009b; 250.
7. Apata ES, Osidibo OO, Apata OC, Okubanjo AO. Effects of different solar drying methods on quality attributes of dried meat product (Kilishi). Journal of Food Research. 2013;2(1):80-86.
8. Myers RH, Montgomery DC. Response surface methodology: Process and product optimization using designed experiment. A Wiley-Interscience Publication; 2002.
9. Yao N, Floros JD, Seetharaman K. Optimization of hard pretzel production. International Journal of Food Science and Technology. 2007;42:269–280.
10. Rayman A, Baysal T, Demirdoven A. Optimization of electroplasmolysis application for increased juice yield in carrot juice production. International Journal of Food Science and Technology. 2011;46:781-786.
11. Arzandeh S, Jinap S. Effect of initial aflatoxin concentration, heating time and roasting temperature on aflatoxin reduction in contaminated peanuts and process optimization using response surface modelling. International Journal of Food Science and Technology. 2011;46:485–491.
12. Koledoye AO, Akanbi CT. Optimization of process conditions for dehulling and softening of locust bean (*Parkia biglobosa,* Jacq. Benth) seeds prior to fermentation in Iru production. International Journal of Postharvest Technology and Innovation. 2013;3(2):123-139.
13. Igene JO. Lipid, fatty acid composition acid storage stability of Kilishi; A sun dried meat product. Tropical Science. 1988;28:156-161.
14. Mgbemere VN, Akpapunam MA, Igene JO. Effect of groundnut flour substitution on yield, quality, and storage stability of Kilishi – a Nigerian indigenous dried meat product. African Journal of Food, Agriculture, Nutrition and Development. 2011;11(2).
15. Badau MH, Igene JO, Collison EK, Nkama I. Studies on production, physicochemical and sensory properties of a standard Kilishi ingredient mix powder. International Journal of Food Science and Nutrition. 1997;48:165-168.
16. Li Y, Liu Z, Zhao H, Xu Y, Cui F. Statistical optimization of xylanase production from new isolated Penicillium oxalicum ZH-30 in submerged fermentation. Biochemical Engineering Journal. 2007;25:195-199.
17. Kalilou S, Collignan A, Zakhia N. Optimizing the traditional processing of beef into Kilishi. Meat Science. 1998;50(1):21–32.
18. Wilhelm LR, Dwayne AS, Gerald HB. Drying and dehydration. In: Food and Process Engineering Technology, St. Joseph, Michigan: ASAE. 2004;259–284.

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